Muons, Inc.

Muons, Inc. Grants and Proposals

Rolland Johnson, Muons, Inc.

In the last four years, several new techniques to cool muon beams have been invented and are under development supported by DOE Small Business Innovation Research grants. Muons, Inc. now has 4 Phase II grants and two Phase I grants. On December 1, Muons, Inc. submitted 5 new Phase I proposals. A short summary of the grants and proposals follows.

In February we will have the first annual low-emittance muon collider workshop at Fermilab. The goal is an end-to-end simulation of a believable muon collider. We need a keynote speaker!

Papers on all that follows at http://www.muonsinc.com
workshop link is at http://www.muonsinc.com/mcwfeb06/

Muon Beam Cooling Innovations

- Many new inventions and reestablishment of the principle that a neutrino factory should be on the direct path to a muon collider
- Muon Colliders need small transverse emittance and low muon flux for many reasons (see workshop main page)
- A Neutrino Factory using a very cool muon beam which is accelerated in a superconducting proton driver Linac may be very cost-effective
- Several new ideas have arisen in the last 4 years which are being developed under SBIR grants and have the potential to form muon beams with transverse emittances of a few mm-mrad

Muons Inc. Funding History

Year	Project	Expected Funds	Research Partner
2002	Company founded		
2002-5	High Pressure RF Cavities	$600,000	IIT
2003-6	Helical Cooling Channel	$850,000	JLab
2004-5	MANX demo experiment	$ 95,000	FNAL TD
2004-7	Phase Ionization Cooling	$745,000	JLab
2004-7	Hydrogen Cryostat	$795,000	FNAL TD
2005-6*	Reverse Emittance Exch.	$100,000	JLab
2005-6*	Capture, ph. rotation	$100,000	FNAL AD

* Can be extended to phase II for +$750,000 and +2 years

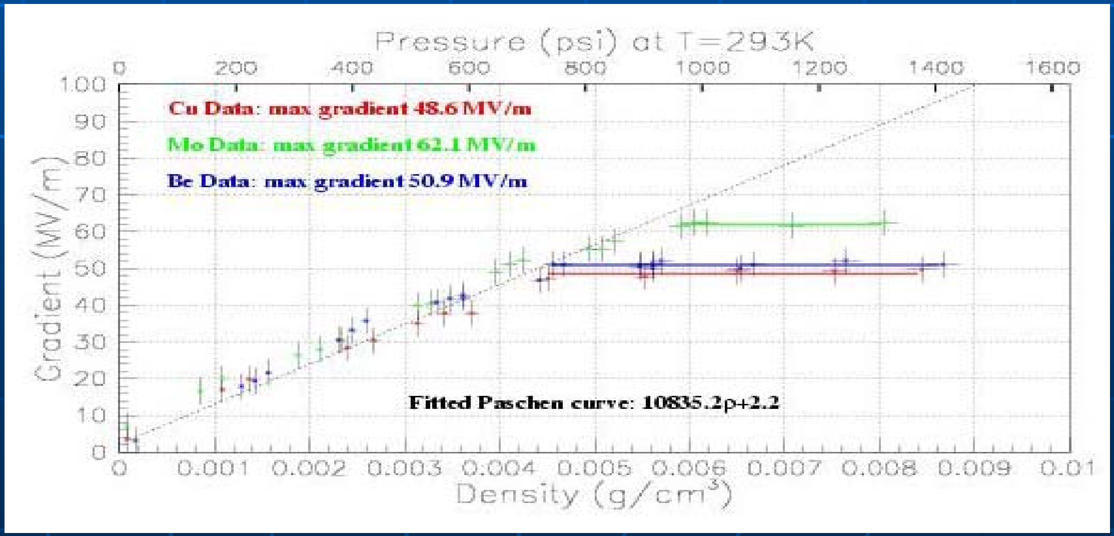
- SBIR/STTR funding: Solicitation September, Phase I proposal due December, Winners in May, get $100,000 for 9 months, Phase II proposal due April, Winners June, get $750,000 for 2 years

Muons, Inc. SBIR/STTR Collaboration:

- BNL
  - Ramesh Gupta, Robert Palmer, Erich Willen
- Fermilab:
  - Victor Yarba, Emanuela Barzi, Licia del Frate, Ivan Gonin, Timer Khabiboulline, Gennady Romanov, Daniele Turrioni, <u>Katsuya Yonehara</u>
  - Dave Neuffer, Chuck Ankenbrandt, Al Moretti, Milorad Popovic, Jim Griffin
- IIT:
  - Dan Kaplan, Linda Spentzouris
- JLab:
  - Yaroslav Derbenev, Alex Bogacz, <u>Kevin Beard</u>, Yu-Chiu Chao
  - Robert Rimmer
- Muons, Inc.:
  - Rolland Johnson, <u>Mohammad Alsharo'a</u>, <u>Mary Anne Cummings</u>, <u>Pierrick Hanlet</u>, Bob Hartline, Stephen Kahn, Moyses Kuchnir, <u>David Newsham</u>, <u>Kevin Paul</u>, Tom Roberts
- <u>Underlined</u> are young full-time accelerator scientists supported by SBIR grants First named are subgrant PI.

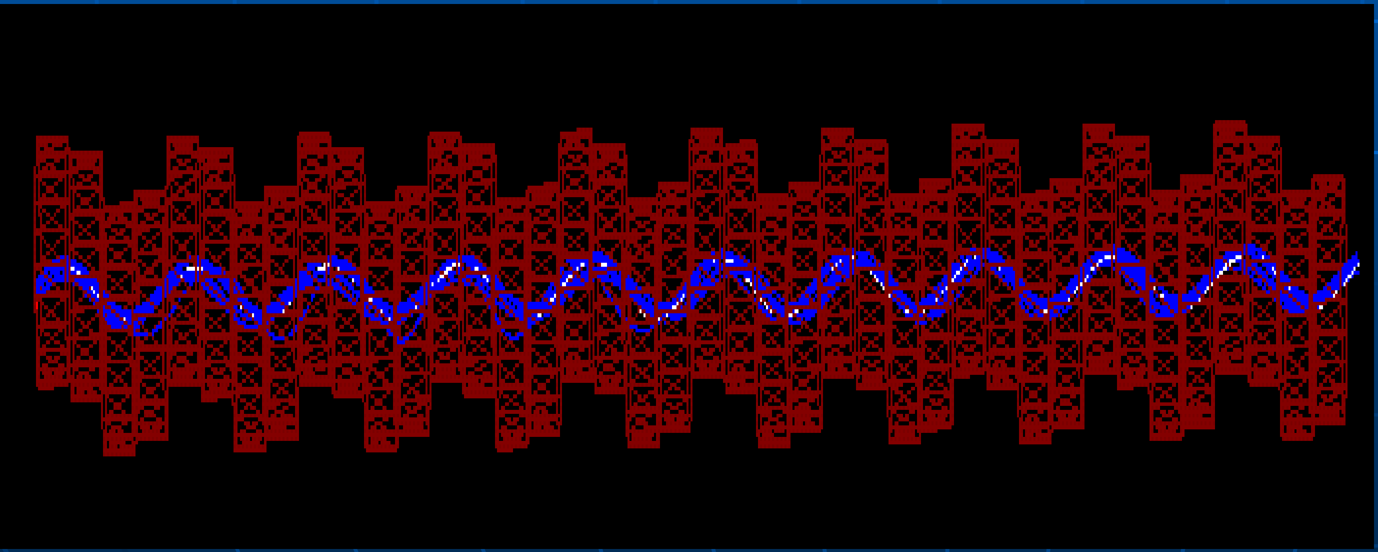
1) Pressurized High Gradient RF Cavities (IIT, Dan Kaplan)

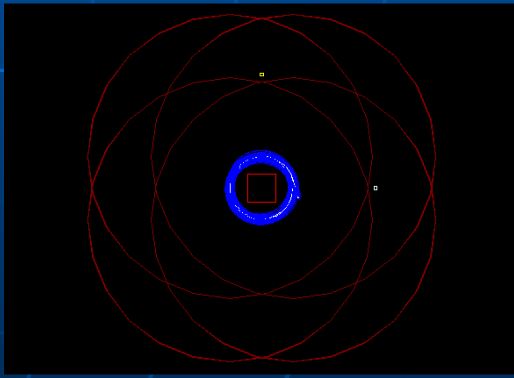
- 800 MHz test cell with GH2 to 1600 psi and 77 K in Lab G, MTA
- Paschen curve verified
- Maximum gradient limited by breakdown of metal
  - fast conditioning seen
- Cu and Be have same breakdown limits (~50 MV/m), Mo ~20% better



2) **Six-Dimensional Cooling in a Continuous Absorber** (JLab, Slava Derbenev)

- Helical cooling channel (HCC)
  - Continuous absorber for emittance exchange
  - Solenoidal, transverse helical dipole and quadrupole fields
  - Helical dipoles known from Siberian Snakes
  - z-independent Hamiltonian
  - Derbenev & Johnson, Theory of HCC, April/05 PRST-AB





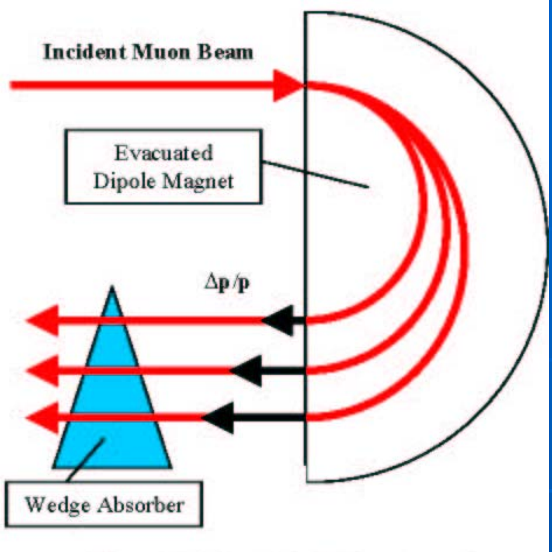


Figure 1. Use of a Wedge Absorber for Emittance Exchange

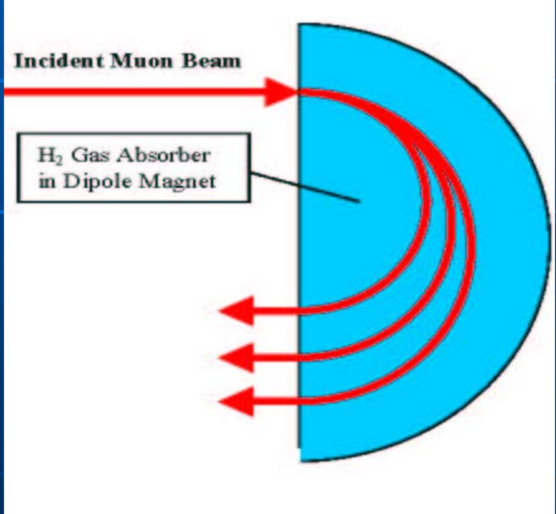
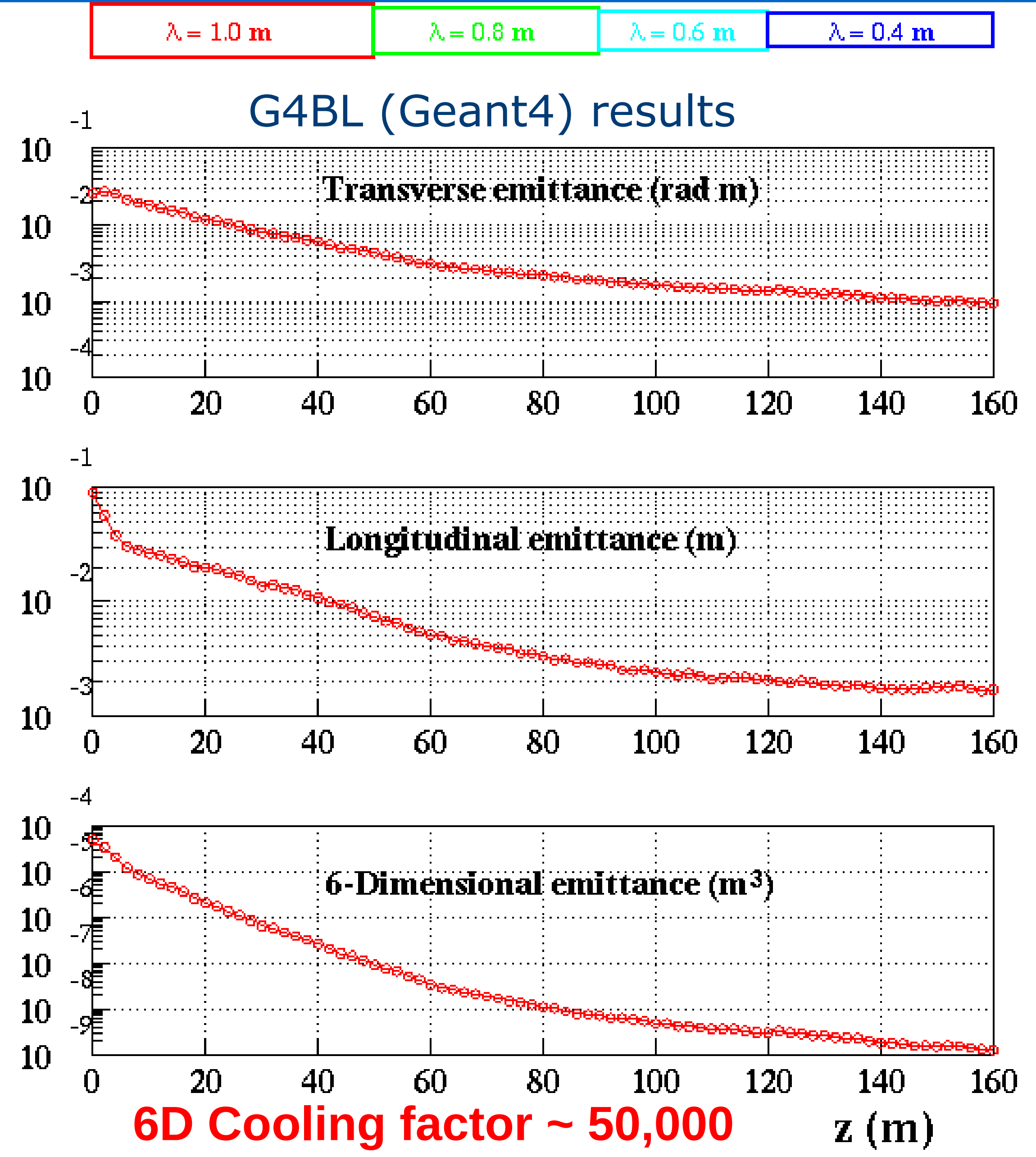


Figure 2. Use of Continuous Gaseous Absorber for Emittance Exchange



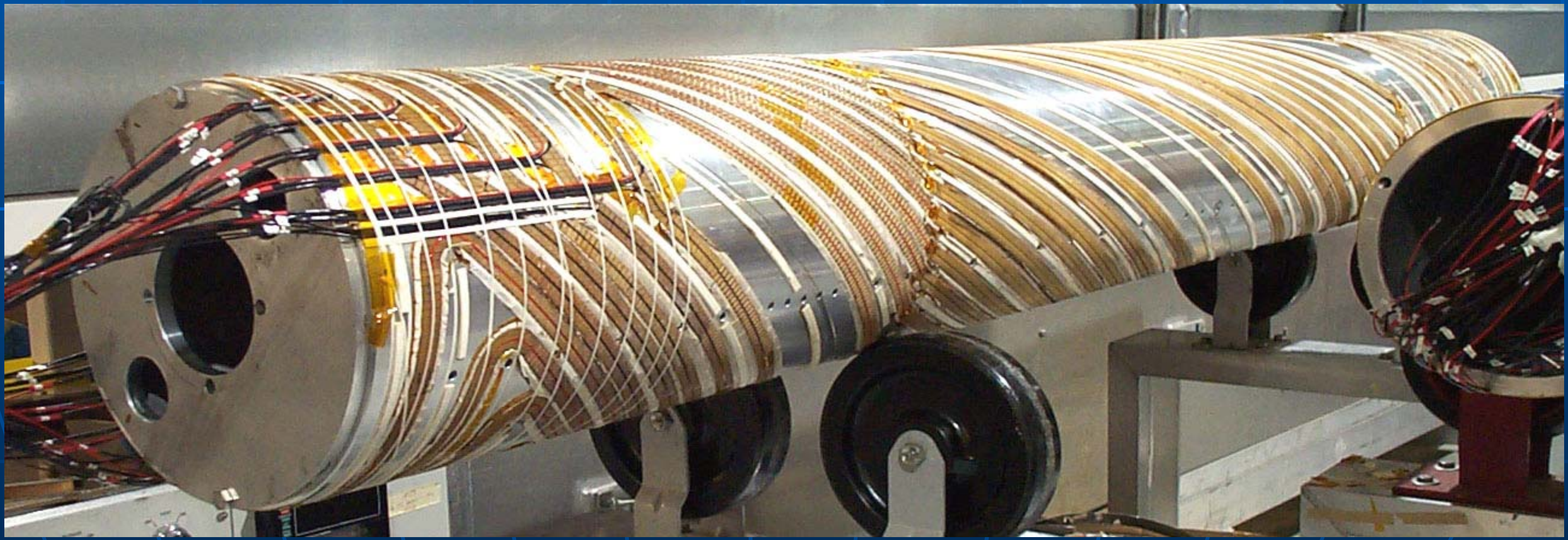
3) **Hydrogen Cryostat for Muon Beam Cooling** (Fermilab, Victor Yarba)

Technology for HCC components:

HTS (nice BSSCO data from TD Ph I), Helical magnet design,

low T Be or Cu coated RF cavities, windows, heat transport, refrigerant

Cryostat for the 6DMANX cooling demonstration experiment (proposal 7)



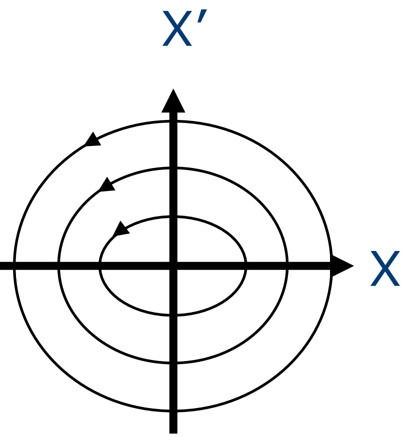
BNL Helical Dipole magnet for AGS spin control

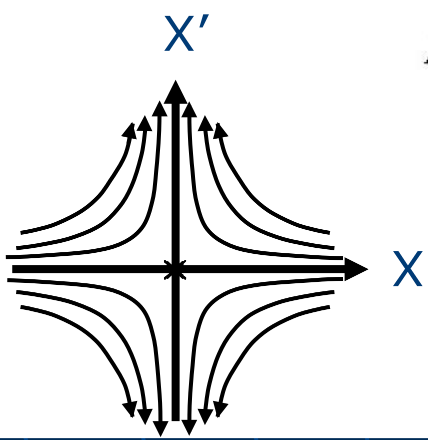
4) Parametric-resonance Ionization Cooling
(JLab, Slava Derbenev)

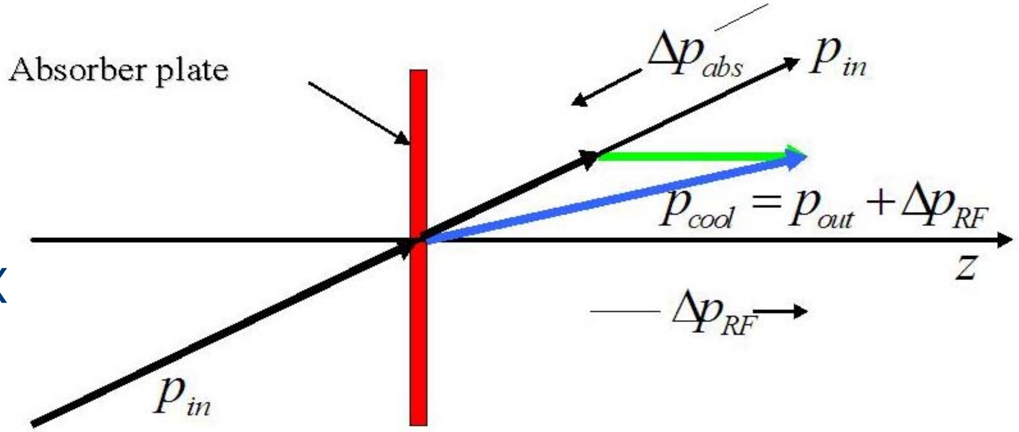
Excite ½ integer parametric resonance (in Linac or ring)

- Like vertical rigid pendulum or ½-integer extraction
- Elliptical phase space motion becomes hyperbolic
- Use xx'=const to reduce x, increase x'
- Use IC to reduce x'

Detuning issues being addressed (chromatic and spherical aberrations, space-charge tune spread). Simulations underway.

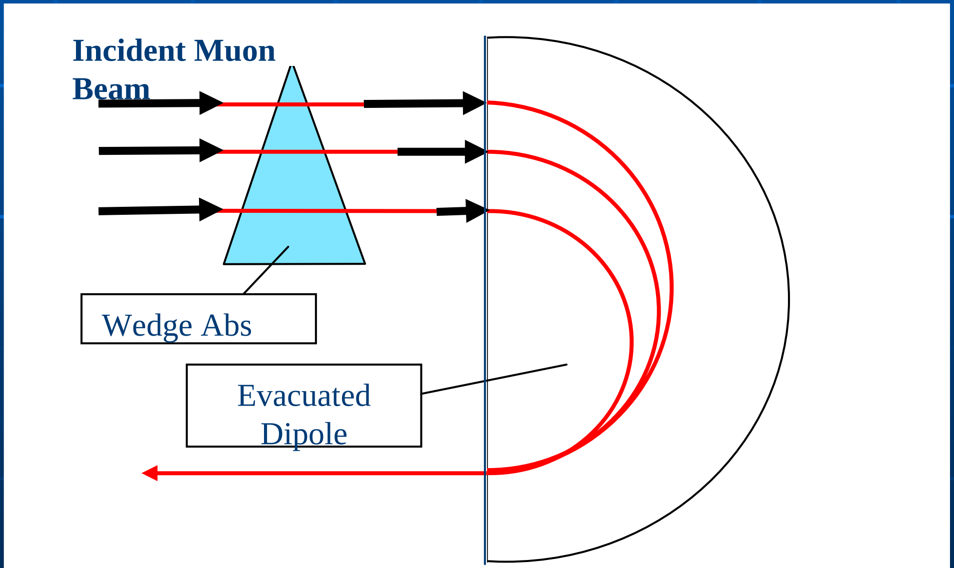




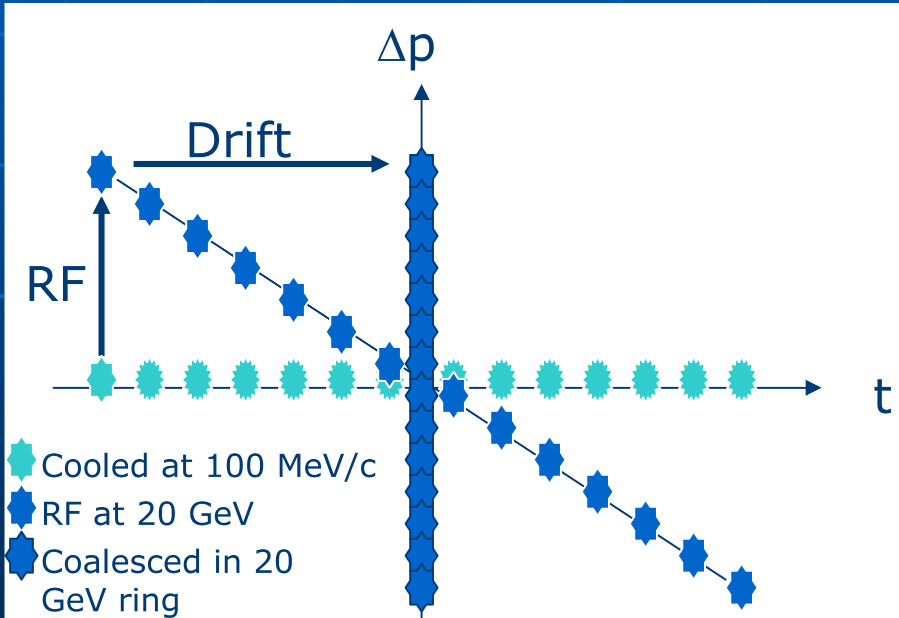


5) Reverse Emittance Exchange
(JLab Slava Derbenev)

- p(cooling)=100MeV/c, p(colliding)=2.5 TeV/c => room in Δp/p space
- Shrink the transverse dimensions of a muon beam to increase the luminosity of a muon collider using wedge absorbers
- 20 GeV Bunch coalescing in a ring a new idea for ph II, due 4/13/05
- Neutrino factory and muon collider now have a common path



Concept of Reverse Emittance Exch.

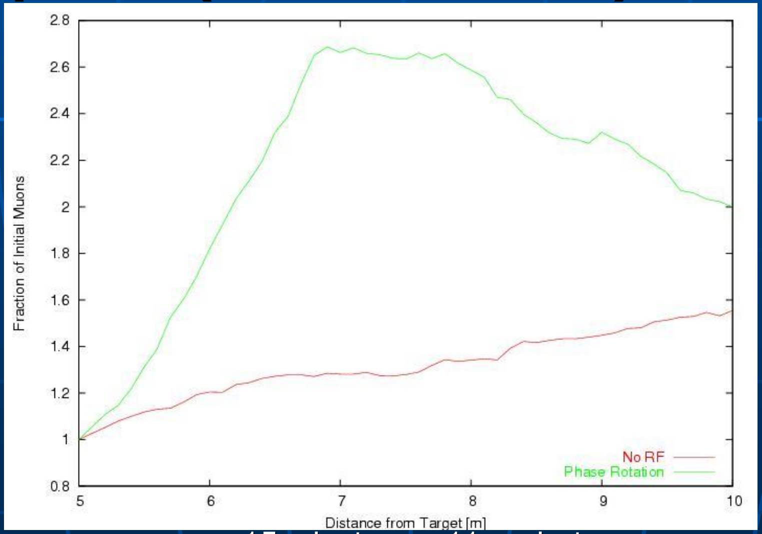


1.3 GHz Bunch Coalescing at 20 GeV

6) Capture, Bunching, and Precooling using HP GH2 RF
(Fermilab David Neuffer)

- Simultaneous muon capture, RF bunch rotation, and precooling in the first stage of a muon beam line
- Phase rotation and beam cooling will be simulated
- Continuation of the HP RF development in the MTA with high magnetic field and high radiation environment

- **We need data from the MTA with the LBNL solenoid and the promise of the MTA beamline for a strong Phase II proposal (due 4/13/05)**



Increase in muons captured when 2 m of bunch rotation RF is applied starting 5 m from target.

MuCool Test Area (MTA)

7) 6D Muon Beam Cooling Demonstration (Fermilab, Victor Yarba)

Helical Cooling Channel (HCC) experiment

500% 6d cooling in 4 m using LHe

8) 50 Tesla HTS Magnets for Beam Cooling (BNL, Ramesh Gupta)

HTS solenoid at 4 K, new technology

Very effective transverse muon cooling

9) Design and Simulation of Beams in Matter (IIT, Dan Kaplan)

G4BeamLine (GEANT4) used by Muons, Inc., MICE

Add GUI and space-charge effects

10) High Power RF couplers for the ILC (JLab, Bob Rimmer)

1.3 GHz RF needed for Muon Colliders or Neutrino Factories, but higher repetition rates will be required

Start with innovative RF windows for ILC, other 1.3 GHz machines

11) Tunable RF Cavities for FFAGs (Fermilab, Milorad Popovic-NP)

New RF cavity design for fast tuning over a wide frequency range

Well-suited to an FFAG or FNAL Booster